

PROCEEDINGS INTERNATIONAL SYMPOSIUM ON ENGINEERING GEOLOGY AND
THE ENVIRONMENT, ORGANIZED BY THE GREEK NATIONAL GROUP OF
IAEG/ATHENS/GREECE/23-27 JUNE 1997

Engineering Geology and the Environment

Editors

P.G. MARINOS

National Technical University of Athens

G.C. KOUKIS

University of Patras

G.C. TSIAMBAOS

Central Public Works Laboratory, Athens

G.C. STOURNARAS

University of Athens

OFFPRINT / TIRE-A-PART



A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1997

Proposals for environmental impact decreasing in a suburban zone of limestone quarries: Southern Madrid Community, Spain

M.A.García del Cura, *Instituto de Geología Económica, C.S.I.C., Madrid, Spain*

S.Ordóñez, *Laboratorio de Petrología Aplicada, Departamento de Ciencias de la Tierra y del Medio Ambiente, Alicante, Spain*

J.A.González Martín, *Departamento de Geografía, UAM, Madrid, Spain*

M.C.Díaz Alvarez, *ETS Ingenieros Agrónomos, UPM, Madrid, Spain*

E.Dapena, *MOPTMA, Madrid, Spain*

ABSTRACT: Over 30 Mm³ of limestones are extracted at least 100 quarries in southern part of Madrid, its environmental impact is described in this paper. Three main reclamation areas are distinguished: surrounding of quarries, faces or highwalls of quarries and the floor. For soil reclamation in the environs of quarries we suggest to sow it with forage of fast growth plants (*Lupinus*, *Tripholium*...), in the floor of quarries is possible a spontaneous revegetation or even may be reclaimed for agricultural uses. For quarried rocks faces previous blasting and/or wider benches are proposed. In opinion of the authors it is necessary to concentrate the limestone extraction in two or three large quarries that allows a best policy and reclamation.

1 INTRODUCTION:

A surface of more than 6 Km² has been impacted to extract over than 30 Mm³ of limestones in at least 100 quarries in southern part of Madrid capital (less than 30 Km from the city) (Fig 1). Some underground quarries (Colmenar de Oreja) was active three centuries ago; these quarries are historical sites to extract building materials for Madrid, mainly dimension stones (Dapena, Ordóñez & García del Cura, 1988). But the main extractive activity is focused in the last thirty years. At present the most important quarries are worked using areal strip-mining, but the quarries of small dimensions, non active at the moment, are contour strip-mining. Many of non active quarries are used as illegal urban and industrial waste disposal. Other visual impacts, together the highwall of the quarries, are the tips of excavation wastes and tailings: artificial hills and terracing.

2 RECOVERED MATERIALS:

The limestones extracted belong to the Upper Unity of Miocene of Madrid Neogene Basin. The general appearance of Upper Unity is lying subhorizontal and consist mainly in fluvial detrital sediments that in the upper part changes to massive limestones in the top of the Upper Unity. The thickness of limestones

varies from 0 to 30 m, and the identified reserves are estimated up to 1000 Mt of highest chemical purity, that may be envisaged as limited for the present day demand of cement raw materials. Limestones may be classified as biogenic carbonates: oncholithic, stromatolitic, tufa limestones and biomicrites (gastropoda, ostracoda, chara) are the most common facies (more information in García del Cura & others, 1994).

The average of chemical composition of limestones may be summarized as follows: SiO₂ less than 7%; CaO up to 49 %; Fe₂O₃ and Al₂O₃ less than 0.75 and 2.75 % respectively. The values of some critical components as SO₃, Cl⁻ and Na₂O+K₂O are always less than 0.7, 0.1, and 1 % respectively.

The average of limestones physical properties may be summarized as follows: water absorption, 1.73%; bulk specific gravity, 2.54 g/cm³; compressive strength, 90 Mpa; sonic velocity, 6.1 Km/s; Poisson's ratio, 0.36; and the modulus of elasticity 50.000 to 60.000 Mpa (more data in Dapena, García del Cura & Ordóñez, 1994).

The main uses of limestones are: a) Portland cement manufacturing; b) lime (quick lime and hydrated lime) manufacturing; c) crushed stones for Portland cement concrete and bituminous concrete plants; d) fillers; and e) dimension and cut stones.

The overburden of limestone are mainly reddish clay deposits with limestone boulders, that are related with some karstification processes associated even with small dolines. The Upper Unit of Miocene, and mainly

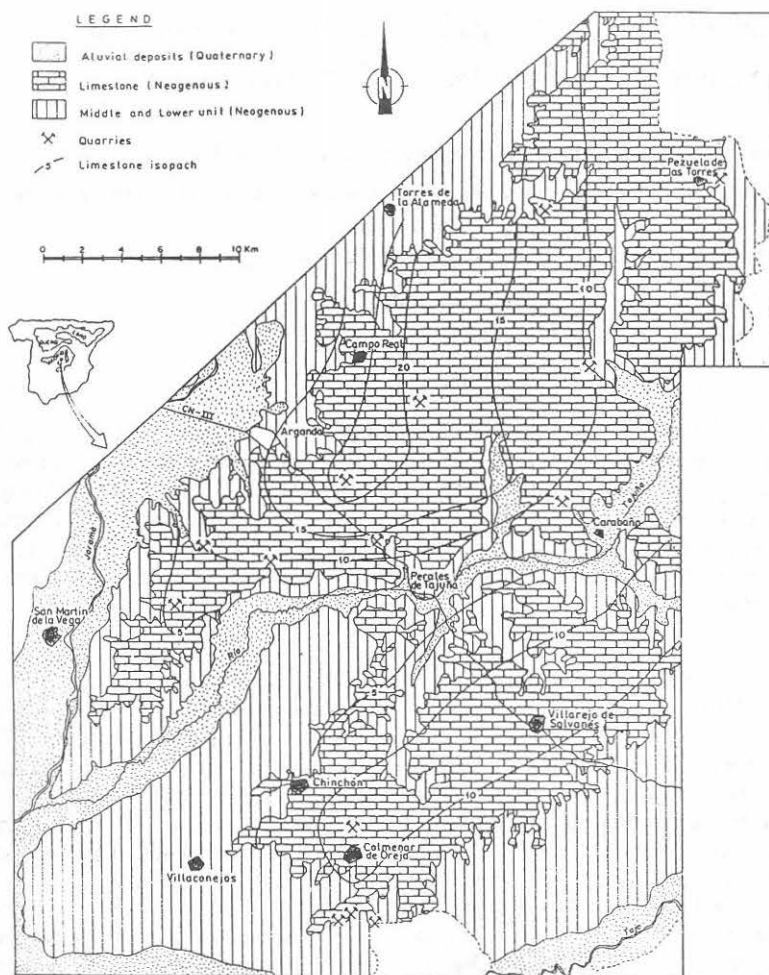


Fig 1. Location and geological map of the quarries zone. In the upper left part it shows a scheme of general location of the zone in Spain.

the limestones, are also the most important regional unconfined aquifer and the thickness of aeration zone is up to 20 m, consequently the limestones extraction and the using of the quarries as waste disposal may impact dangerously regional groundwaters.

3 ENVIRONMENTAL IMPACTS

The soil of the quarries zone is not well developed, its thickness is less than 0,3 m, the vegetation is scarce, mainly brushwood and aromatic plants. Non-impacted soil consists of an A-horizon that varies

from argillaceous to arenaceous composition, and a K-horizon that is developed under the extracted material. Soils may be classified as Aridisols or Inceptisols. As a consequence of their textures and structures these soils may be affected seriously by erosion.

The agricultural activities are focused in cereal of unirrigated land and olive groves. The olive groves are mainly located on soft materials where the A-horizon of soil has been destroyed by a previous deforestation and subsequent related erosion. The present-day erosion may be estimated by the fact that some young olive tree roots are 10 to 30 cm over the soil surface.

The most important quarries has been cartographed

describe and quantify the following: a) anthropic morphology induced by extraction of limestones (highwalls, benches,...); b) risks related with these morphologies (rock falls, rock slides); c) surface of zone exploited (holes, drainage network) d) mine wastes, tailings, crushed stone, stockpiles,...; e) natural revegetation (fig 2 and fig 3). Data from this specific cartography are used to establish the environmental impacts and to make proposals for the environmental recuperation.

The temporal impacts may be summarized in relation with the specific activity in a semiarid region as follows: a) drilling and blasting in the quarries (noise and dust); b) crushing and screening plants (noise and dust); c) stockpile of crushed stone (dust); d) lime and Portland cement plants (dust and combustion gases); e) concrete plants (noise and dust). The permanent impacts are: a) quarries visual impacts, even from the air, because the zone is near Barajas airport, and the high of the near vertical faces are up to 10 m; b) quarries waste visual impacts; c) soils destruction; d) aquifer destruction and decreasing of water infiltration, and when the quarries are used as waste disposal, aquifer pollution.

4 QUARRY RECLAMATION

From the point of view of soils reclamation of quarries zone, we distinguish three main reclamation areas for each quarry,

- Surrounding of quarry.
- Faces of quarry.
- Floor of quarry.

4.1. Surrounding of quarries

These zones are not directly affected by extraction but some impact may be identified:

- a) High rate erosion and dryness of soils even with gently slope, as a consequence of the excavation of quarry.
- b) Dust and even boulder or blocks that cover the soil in the lower part of some tailings stockpiles.
- c) Collapsed soils and damaged soils.
- d) Low organic content in soils.

For soil reclamation in this area we may suggest to sow it with forage plants of fast growth plants (Lupinus, Trifolium...)

Before the sowing, soils ought to be manured and lightly fertilized. The biomass generated may be used to increase the organic content of soils. When

the slope is up to 20% it is necessary to terrace the soils using small walls, or other common agricultural techniques to decrease the erosion rate.

4.2 Quarried rock slopes (high walls)

This is the most important visual impact of this mining activity, generally they are vertical and the highest wall is up to 10 m. Longitudinal extension may reach in the biggest quarries up to 400 m.

It is generally desirable to treat the surrounding quarry faces in order to reduce rockfall and to enhance the visual appearance.

It is possible to make landform replication with restoration blasting techniques on quarried rock slopes and using the civil engineering techniques that are commonly applied to road cutting. In this zone the construction of a landform similar to that in the surrounding natural landscape is easy to make because the arrangement of horizontal strata is very favourable.

We are in agreement with Gun & Bailey (1993) and Gagen, Gunn & Bailey (1993), after these authors the natural development of a blasted rock face is predictable and the stability of that areas of face (which will be more or less stable), can be identified by geomorphological mapping. In largest quarries restoration blasting aims to produce landform sequences by the construction of skeletal rock landforms which not only mimic the outward form of their natural counterparts but can be predicated to evolve in harmony with the operation of natural processes.

Commonly it is not possible the natural revegetation of quarry faces, only when the slopes are deeply modified using waste refill and/or blasting techniques. In order to obtain a cheapest and faster vegetation trial of this area is suitable to make 25 cm wide steps in the quarry face. The slope of steps (2-3%) has to be able to drain the rain water. Each slope may be imagined as a "window box" or "flower pot", that may be refilled with the wastes of exploitation, and/or soil eroded in the upper part of the quarry face. The window boxes will be spontaneously colonized by indigenous surrounding vegetation (*Aegilops geniculata*, *Avena sativa* and *Medicago sativa*, Arranz and Hidalgo, 1992) or may be artificially sown.

4.3. The floor of quarries

The floor of quarries consists mainly in marly and/or sandy sediments of middle permeability, commonly compacted by the stripping and transport machinery

1-GEOLOGY AND GEOMORPHOLOGY

	Neogenous limestone
	Tuffas
	Anticlinal axe
	Synclinal axe
	Faults
	Regional slope
	Dip slope
	Zones jointed
	Structural small cliffs
	V-shaped valley
	U-shaped valley
	Non-structured colluviums
	Soils
	Argilic paleosoils
	Paludinal horizon (calcareous crust)

2-MAN-MADE FEATURES

	Non-active quarry face >10m
	Non-active quarry face 5 to 10m
	Non-active quarry face < 5m
	Active quarry face (>10m)(5 to 10m)(<5m)
	Failure cracks
	Smoothed quarry faces
	Vertical quarry faces
	Natural smoothed slopes of waste tips
	Residual hills
	Depressions
	Irregular surfaces
	Planation surfaces
	Ramp surfaces
	Toppling
	Small bad-lands
	Gravitational processes

3-MAN-MADE DEPOSITS

	Gravitational deposits of blocks
	Dimension stone deposits
	Bulk stockpiles
	Mill stone stockpiles
	Tailing stockpiles
	Soil dumps
	Waste disposal: construction and demolition (E) and garbage and rubbish (B)

4-OTHER SYMBOLS

	Building and material processing plant
	Access road
	Ephemeral ponds
	Height (a.s.l.)
	Non-active railway
	Conveyors
	Roads
	Old tailing stockpiles

5- SOIL USES

	Brushwood		Cereal of unirrigated land
	Vine yard		Pine afforestation
	Olive trees		Deciduous tree afforestation
	Scrub land		
	Olive grove		

Fig. 2 Legend used for mapping geomorphological, soil uses, man-made features and deposits. This legend is used for each of quarry zones identified. See the fig. 3.

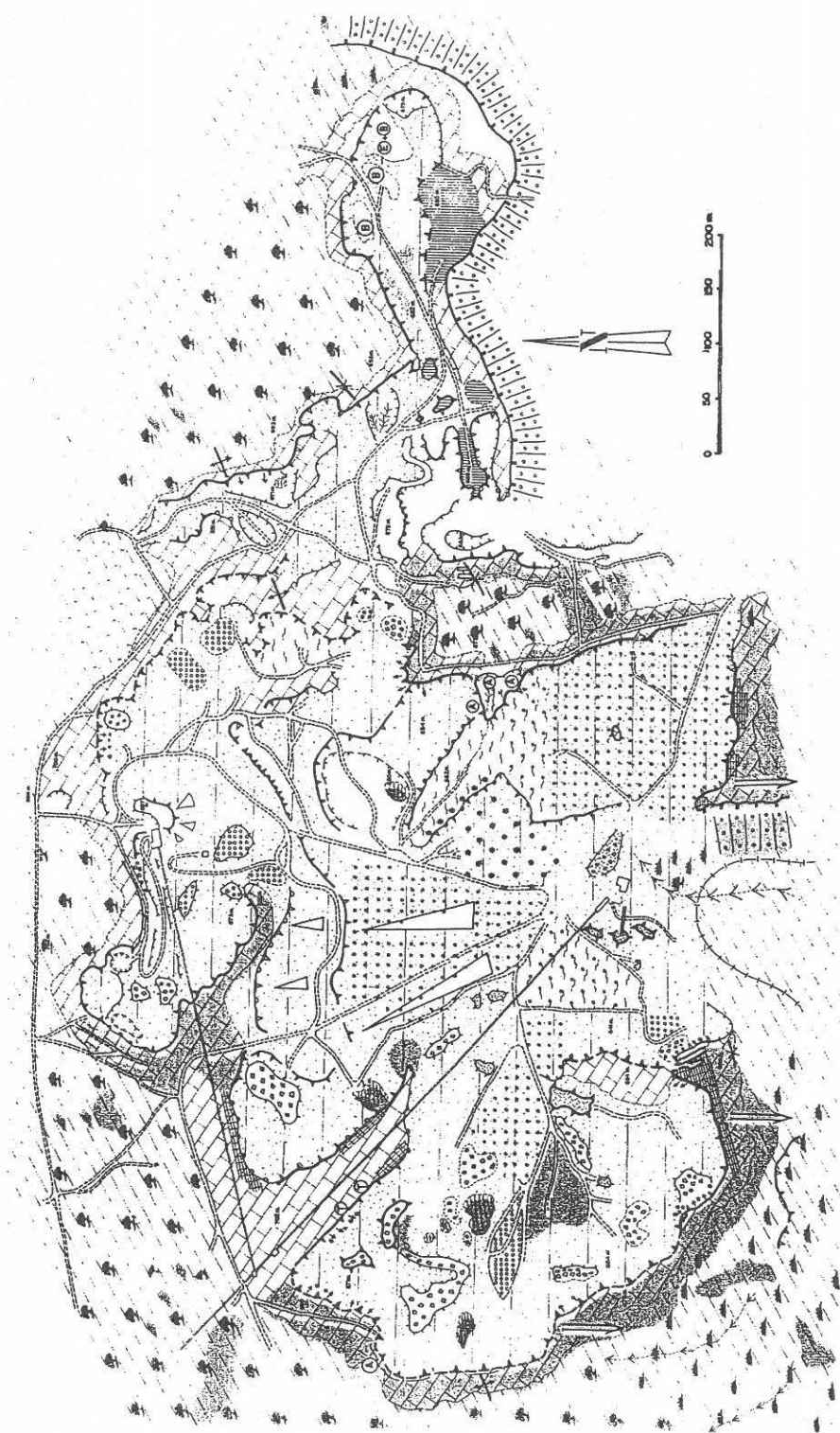


Fig. 3 Geomorphological and soil uses map of the quarries located western Arganda-Morata de Tajuña Road.

movement in the quarry. As a consequence of this compactation for the reclamation of this area the floor of quarries would be previously flat to avoid the development of ephemeral ponds in the winter, and after would be ploughed to fluff up the soil. It is possible a spontaneous revegetation or even may be reclaimed for agricultural uses, as the climatic conditions are not adequate for afforestation (pine or deciduous tree)

5 PROPOSALS FOR ENVIRONMENTAL IMPACT DECREASING

5.1 Non active quarries

The proposals for impact correction in non active quarries: a) The area strip-mining quarries: may be used after impermeabilization as parks, stadiums, parking, industrial land,... and even as non toxic waste disposal. At the moment one of the most important non-active quarry, near Los Santos de la Humosa (N part of the map) is used as four wheel drive racetrack. Two big quarries, are used as legal waste disposal b) The contour strip-mining, ought to be restored to original contour using mining waste and tailings, or terracing and in any case reestablishing vegetation. Semiarid climate of this region does not help the development of spontaneous revegetation.

The reclamation of small quarries, mainly contour-strip mining, would be start by a slope correction using the waste tips and/or blasting the quarry faces. The visual impact quarries as a consequence of the mining type is highest than other biggest quarries worked using areal strip-mining.

5.2 Active quarries

In the active quarries it is necessary:

- a) To regulate news activities;
- b) To restore soil and vegetation after extraction.

The soil would be scraped and dumped, to use it in the mined areas reclamation. We suggest the use of natural revegetation, mainly indigenous brushwood species.

c) Mining companies licensed for rocks extraction ought to watch to prevent the dumped of dangerous wastes in the floor of the quarries, because of the high vulnerability of the aquifer lying under limestone. The residence time of water in this aquifer is 15-30 years, after Maestro, Llamas & Rubio (1986), and as consequence the aquifer has a low capacity of self-purification.

d) A long-term proposal may be to concentrate the extraction of limestones in two or three sites. These bigger quarries, mined using areal strip-mining method, may be easily integrated from geomorphological point of view in the Páramo landscape, this may be considered as an erosional peneplain developed over Neogenous limestones and only locally trenched by the Quaternary fluvial network.

e) The concentration of the extractions of limestones may help the integral recovery of limestones. To draw up a plan for an integral exploitation of limestones, and even of the overburden materials. This plan may be thought as a recovery by steps. So, after the extraction of blocks to obtain dimension and cut stones, some selected wastes may be used as raw materials for crushed stones, after this some wastes may be used for make fillers, and overburden, materials and of course fines, and tailings may be used as raw material for clinker of Portland cement.

This study has been supported by the CAM (*Madrid Community Government*) (Research Project C 190-90).

REFERENCES

- Arranz, J.C. & Hidalgo Castro, M.N. 1992. Observaciones sobre la colonización vegetal en taludes excavados de carretera en la Comunidad Autónoma de Madrid. *Bol. Geol. Min.* 103-5, 921-934.
- Dapena, E., García del Cura, M.A. & Ordóñez, S., 1994. Characteristics of tertiary limestones in the Madrid are for use as construction materials, *7th Congress Int. Ass. Engineering Geology*, V, 3269 - 3278.
- Dapena, E., Ordóñez, S. & García del Cura, M.A., 1988. Study of the limestone rock used in the construction of palaces in Madrid during 18th and 19th centuries. *5th Congress Int. Ass. Engineering Geology*, 683.
- Gagen, P., Gunn, J. & Bailey, D. 1993. Landform replication experiments on quarried limestones rock slopes in the English Peak District. *Z. Geomorph.* 87, 163-170.
- García del Cura, M.A. Ordóñez, S. Dapena & González Martín, J.A.. 1994. Las canteras de calizas de los interfluvios de los ríos Jarama - Tajúña - Tajo en la Comunidad de Madrid: Valoración de recursos. *Bol. Geol. Min.* 105-6; 574-590.
- Gunn, J. & Bailey, D. 1993. Limestone quarrying and quarry reclamation in Britain. *Environmental Geology*, 21, 167-172.
- Maestro, M.T., Llamas, M.R. & Rubio, P.L. 1986. Contribución al conocimiento hidrogeoquímico de las calizas de los Páramos. *Jornadas sobre el karst en Euskadi. Comunicaciones.* 1, 275-285.

FROM THE SAME PUBLISHER:

Oliviera, R., L.F.Rodrigues, A.G.Coelho & A.P.Cunha (eds.) 90 5410 503 8

7th International Congress International Association of Engineering Geology – Proceedings / Comptes-rendus, Lisboa, Portugal, 5-9-9 September 1994

1994, 25 cm, 5240 pp., 6 vols, Hfl.850 / \$490 / £320

The broad range of themes reflects the wide spectrum of activities within Engineering Geology as well as its concern with the most actual matters which affect mankind like natural hazards and environmental protection. Methods & techniques of ground study, construction materials, surface & underground works as well as information technologies & the teaching, training & professional practice of engineering geology are also extensively covered.

Price, D.G. (ed.) 90 6191 130 3

6th international congress International Association of Engineering Geology – Proceedings / Comptes-rendus, Amsterdam, Netherlands 6-10 August 1990

1990, 28 cm, 5000 pp., 6 vols, Hfl.1220 / \$695.00 / £498

Marinos, P.G. & G.C.Koukks (eds.) 90 6191 793 X

The engineering geology of ancient works, monuments and historical sites: Preservation and protection – Proceedings / Comptes-rendus of an international symposium, Athens, 19-23 September 1988

1988, 25 cm, 2388 pp., 4 vols, Hfl.595 / \$340.00 / £242

Barends, F.B.J., F.J.J.Brouwer &

F.H.Schröder (eds.) 90 5410 589 5

Landsubsidence: Natural causes / Measuring techniques / The Groningen gasfields – Proceedings of the fifth international symposium on landsubsidence, The Hague, Netherlands, 16-20 October 1995

1995, 25 cm, 426 pp., Hfl.150 / \$85.00 / £61

Subsidence occurs in many parts of the world, particularly in densely populated deltaic regions, causing extremely expensive damage. Subsidence has resulted from natural causes, from man-induced causes, or from other mixed causes and shrinkage of organic deposits, or the development of sinkholes in karstic terrain.

Hawkins, A.B. (ed.) 90 5410 866 5

Ground chemistry: Implications for construction – Proceedings of the international conference, University of Bristol, UK, 1992

1997, 25 cm, 672 pp., Hfl.195 / \$105.00 / £66

The disturbance of the status quo as a consequence of engineering works has given rise to many problematic situations, created new problems and exacerbated existing ones. Changes in such conditions as ground water, temperature and the weathering state of the exposed material lead to chemical reactions which may facilitate the formation of new minerals with different volumes or create environments particularly conducive to the proliferation of bacteria.

Viggiani, C. (ed.) 90 5410 871 1

Geotechnical engineering for the preservation of monuments and historical sites – Proceedings of an international symposium, Naples, 3-4 October 1996

1997, 25 cm, c.600 pp., Hfl.195 / \$110.00 / £66

The interactions between geotechnical engineering and the preservation of monuments and historic sites is well exemplified by cases as the Tower of Pisa, the Cathedral of Mexico City, and a number of archaeological sites. Two lectures deal with the integrated approach to the safeguard of monuments and the geotechnical problems of the ancient Egypt. Three general reports provide a systematic appraisal of the state of the art.

Grigorian, A.A. 90 5410 763 4
Pile foundations for buildings and structures in collapsible soils

1997, 24 cm, 158 pp., Hfl.95 / \$55.00 / £32 (No rights India)

Contents: Collapsible soils as basis for structures; Relations of piles and pile foundations with collapsible soil under the action of external loading and intrinsic bed weight; Basic premises, designs and methods of designing piles in collapsible soils; Designing pile foundations for buildings and structures in collapsible soils; Construction of buildings and structures on pile foundations in collapsible soils.

Saran, Swami 90 5410 297 7

Analysis and design of substructures – Limit state design

1996, 24 cm, 868 pp., Hfl.135 / \$80.00 / £55 (No rights India)

The book offers a systematic treatment of the analysis and design of substructures. The aim is to deal with a substructure in its entirety, involving soil exploration, testing analysis and structural design. The book covers the major types of foundations and retaining structures including footings and rafts, piles and wells. Contents: Engineering properties of soils; Soil exploration; Lateral earth pressure; Limit state design – Basic principles; Foundation design – General principles; Shallow foundation; Pile foundation; Bridge substructures; Marine substructures; Rigid retaining walls; Sheet pile walls; Foundations in expansive soils; Foundations of transmission line towers; Reinforced earth.

Kutzner, Christian 90 5410 634 4

Grouting of rock and soil

1996, 25 cm, 286 pp., Hfl.175 / \$99.00 / £69

Grouting is a proven but complex method to seal and to stabilize substrata. This book deals with the design and execution of grouting works in all kinds of rock and soil, including jet grouting. Design principles are discussed whereby different approaches, exercised in different parts of the world, are compared to each other and evaluated. The work performance including the necessary machinery and accessories is explained with the aid of many examples from practice. Considerations are made of conventional and advanced methods of tendering and contracting. The readers are invited to participate in prestigious tasks in many countries of the world and to follow up the approach to solve them.

Ochiai, H., N.Yasufuku & K.Omine (eds.) 90 5410 833 9

Earth reinforcement – Proceedings of the international symposium, Fukuoka, Kyushu, Japan, 12-14 November 1996

1996, 25 cm, c.1200 pp., 2 vols, Hfl.245 / \$150.00 / £100

The papers are arranged under five categories which cover almost all aspects in the area of earth reinforcement: Testing and materials; Embankments; Wall structures; Foundations; Slopes and excavations. The second volume contains texts of the special and keynote lectures, texts of the special reports on the performance of earth reinforcement structures under the latest two great earthquakes, reports of technical session chairmen and discussion leaders as well as concluding remarks.

Yonekura, R., M.Terashi & M.Shibazaki (eds.) 90 5410 805 3

Grouting and deep mixing – Proceedings of the second international conference on ground improvement geosystems, Tokyo, 14-17 May 1996

1996, 25 cm, 1062 pp. 2 vols, Hfl.245 / \$150.00 / £99

Recently soft and plain ground areas have been more & more utilized in the world due to economical development. Consequently, ground improvement technologies are becoming important. Topics: Grouting; Deep mixing; Engineering properties of materials and improved soils; Equipment, execution, and process control; Design guidelines & engineering manual with evaluation; Applications; New concepts & technologies.

All books available from your bookseller or directly from the publisher:

A.A. Balkema Publishers, P.O. Box 1675, NL-3000 BR Rotterdam, Netherlands (Fax: +31-10-413-5947)
For USA & Canada: A.A. Balkema Publishers, Old Post Rd, Brookfield, VT 05036-9704 (Fax: 802-276-3837)